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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):

A Razak, A. H., & Skov, A. L. (2016). *Silicone elastomers with aromatic voltage stabilizers*. Abstract from 6th International Conference on Electromechanically Active Polymer (EAP) Transducers & Artificial Muscles, Helsingør, Denmark.

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Silicone elastomers with aromatic voltage stabilizers

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Electrical breakdown causes short-circuiting of dielectric elastomers (DEs) resulting in irreversible destruction of the DE. The electrical field at which the un-actuated elastomer breaks down is known as the electrical breakdown strength. Numerous studies have been performed in order to obtain elastomers with high relative permittivity and low Young's modulus in order to increase the actuation performance at a given voltage, but the optimised elastomers often possess relatively low electrical breakdown strength. On the other hand, increasing the electrical breakdown strength of DEs allows for larger actuation due to the possibility of utilizing larger electrical fields.^{1,2} Many studies on electrical breakdown of pre-strained DEs have been conducted, however less efforts have been focused on improving the electrical breakdown strength such as by blending in additives or by polymer structure modifications. In order to increase the electrical breakdown strength of polymers for e.g. the cable industry, additives like aromatic voltage stabilizers are used. Earlier works on using voltage stabilizers in polymers have mainly focused on polyethylene with the purpose of reducing power loss for high voltage insulation cables.³⁻⁵ As an alternative to utilise additives as voltage stabilizers, grafting aromatic compounds to silicone backbones may overcome the common problem of insolubility of the aromatic voltage stabilizer in the silicone elastomers due to phase separation. Preventing phase separation during preparation and during operation is a key requirement for long life-times of DEs.⁵

A method to synthesise a polydimethylsiloxane-polyphenylmethylsiloxane (PDMS-PPMS) copolymer with electron-trapping effects has been developed utilising a quick hydrosilylation reaction at ambient temperature and crosslinking via hydrosilylation by a vinyl-functional crosslinker. The mechanism of electron-trapping by aromatic compounds grafted to silicone backbones in a crosslinked PDMS is illustrated in Fig. 1. The electrical breakdown strength, the storage modulus and the loss modulus of the elastomer were investigated, as well as the excitation energy from the collision between electron carriers and benzene rings in PDMS-PPMS copolymer was measured by UV-vis spectroscopy. The developed elastomers were inherently soft with enhanced electrical breakdown strength due to delocalized pi-electrons of aromatic rings attached to the silicone backbone. The dielectric relative permittivity of PDMS-PPMS copolymers remained between 2 to 3 with low conductivity and low dielectric loss as well as high storage moduli with low viscous loss, thereby maintaining the electro-mechanical integrity of the elastomer.

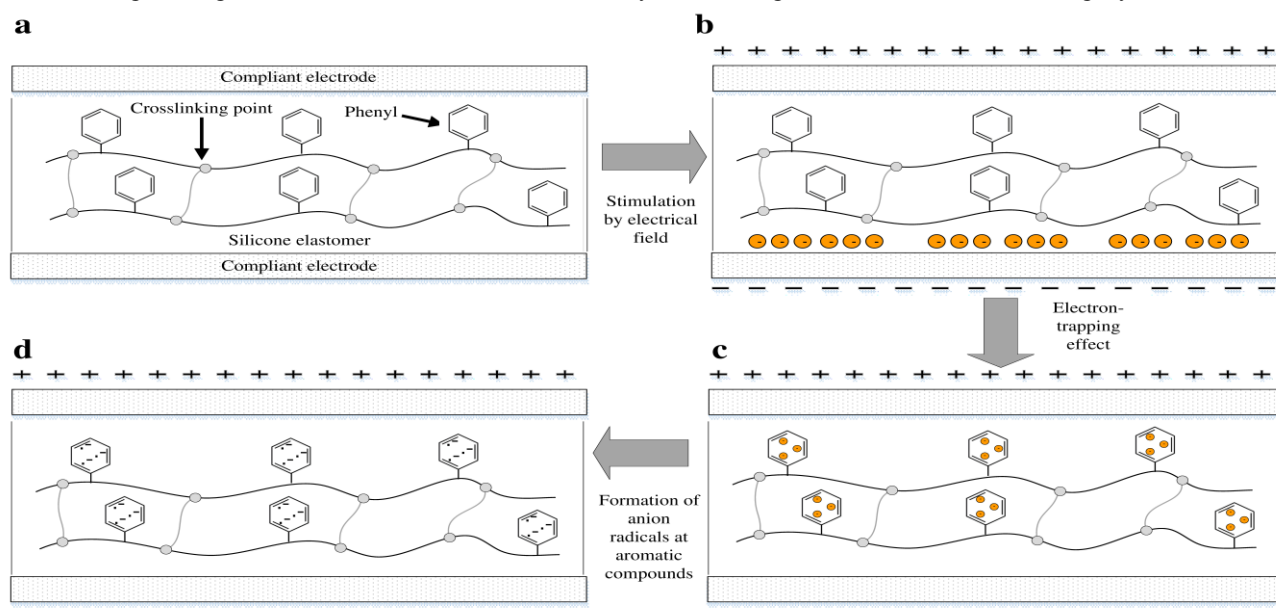


Fig. 1 A mechanism of electron-trapping: a) A silicone elastomer with aromatic compounds attached to silicone backbone and sandwiched between two compliant electrodes. b) The existence of electrons at an interface between the elastomer and the compliant electrode in a presence of electrical field. c) The electron-trapping effect as a consequence of collision between electrons and aromatic rings. d) The formation of anion radicals resulted from disturbance of the cloud of π -electrons.

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